

SPAM: A New Tool for Monitoring Solar Energetic Particle Impacts to Satellite Operations

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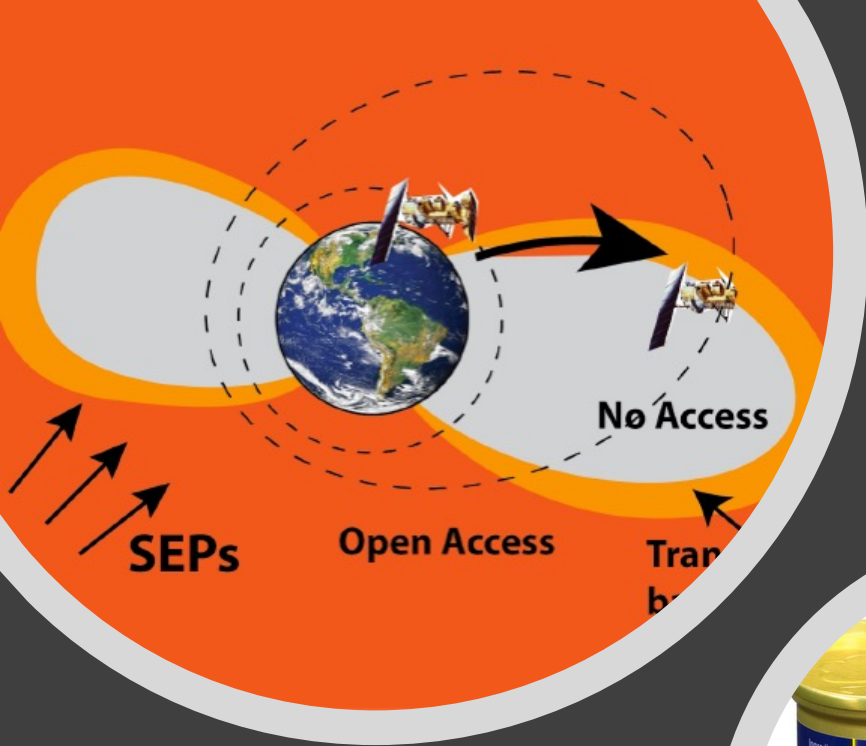
T.P. O'Brien, R. Quinn, S. Huston, P. Whelan, N. Reker



SPAM

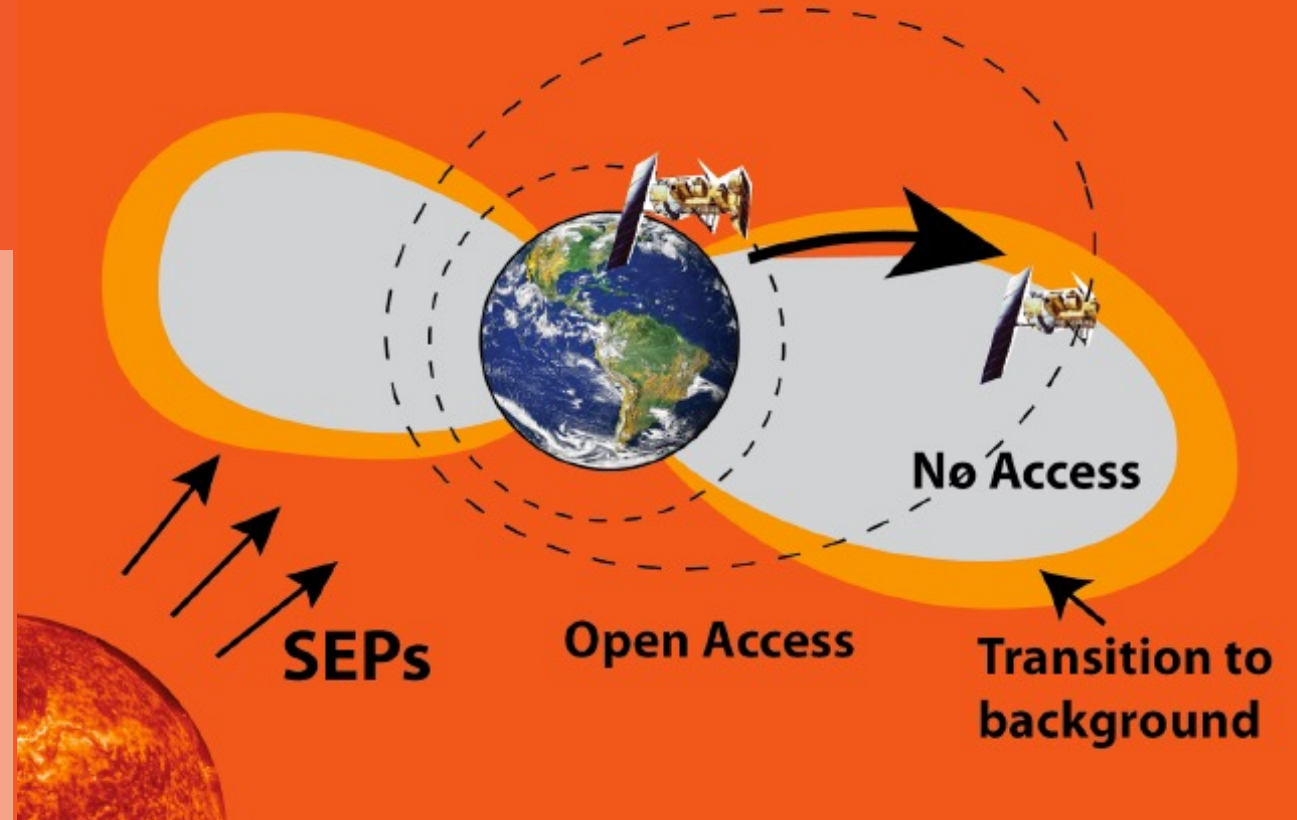
Solar Particle Access Model

An empirically derived data driven model for mapping solar particle flux throughout the magnetosphere for satellite anomaly monitoring and attribution

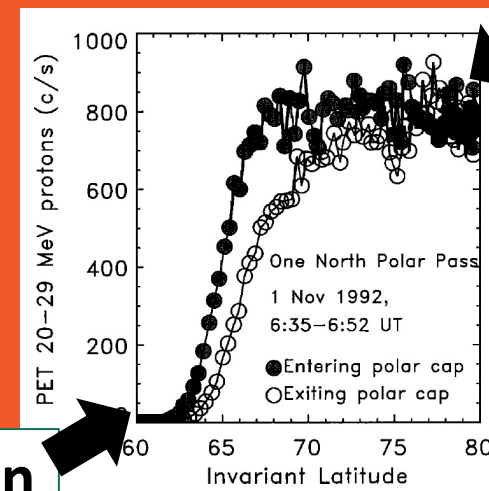


Why SPAM?

- During a solar energetic particle (SEP) event, high energy ions streaming from the sun flood near Earth space for days to weeks.
- These ions can pass through satellite microelectronics causing device failure or uncommanded mode/state changes.
- Some regions are shielded as ions are deflected by Earth's magnetic field.
- Polar orbiting MEO/LEO satellites will pass in and out of high flux regions.
- Monitoring the threat from these ions requires knowledge of where they have access or are deflected.



Particle Flux



Polar Cap

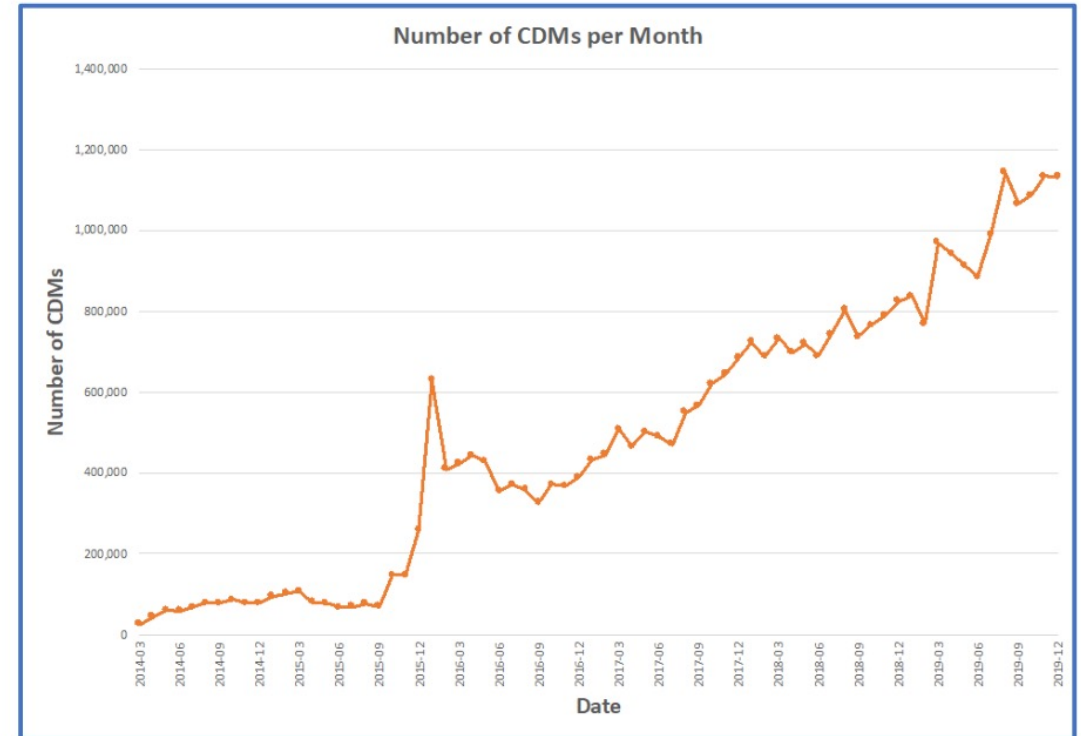
Shielded region

Leske et al., 2001

Why SPAM?

- Increasing # of satellites in orbit
 - Projected 50,000+ in LEO
- Space weather and SEPs are an overlooked aspect of Space Traffic Management
- Upsets caused by SEPs are an unknown threat
 - Last event in 2017
- An issue for one satellite can escalate to an issue for many (i.e Galaxy 15 zombiesat)
- Forensic tools for monitoring/identifying SEP related anomalies are limited

Number of CDMs per Month



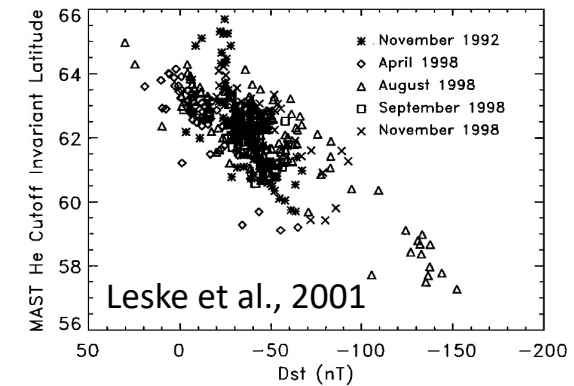
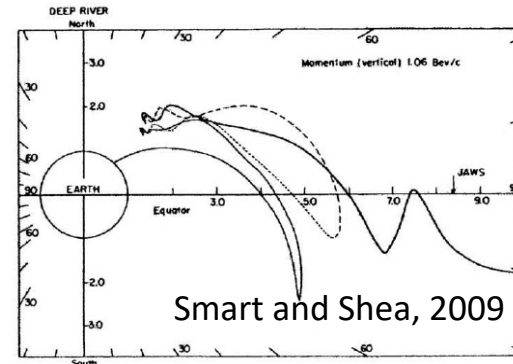
Source: 18th Space Control Squadron (DoD)

27 “emergency” Conjunction Data Messages (CDMs) sent daily in 2019 to warn operators of possible collisions

Why SPAM?

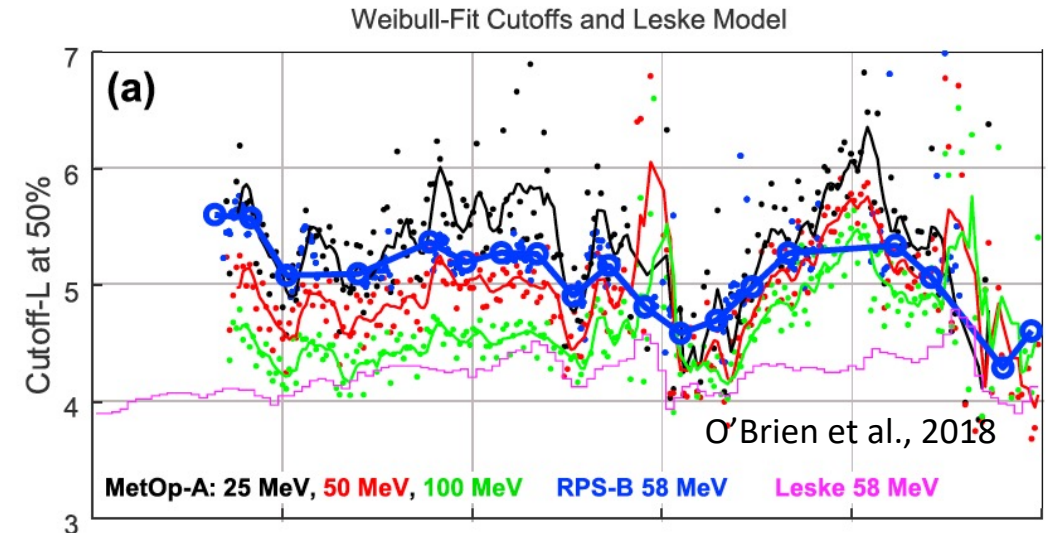
Current models:

- Physics based: trace particle trajectories
- Statistical: Define average locations based on past event

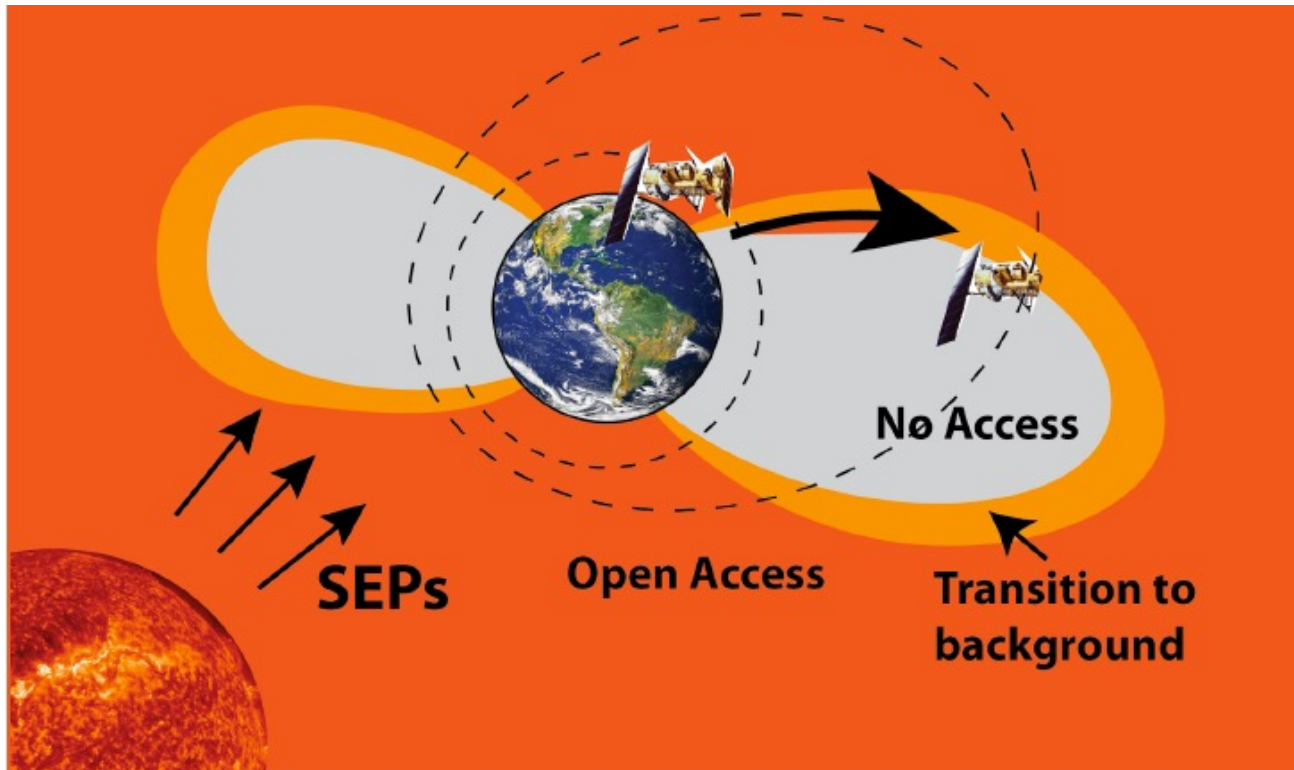


Issues:

- Don't capture the observed dynamic variations
- Give single cutoff locations and don't describe how the flux increases across that boundary which is important for satellite impacts.
- Are not easily accessible to satellite operators.



Benefits of SPAM



Measures SEP access regions using real time LEO observations (POES/MetOP)

Instead of providing one cutoff boundary, the flux profile is described by a Weibull function.

Captures MLT variations

Maps flux to all altitudes with functional fits created from comparing high and low altitude satellite observations

Available as a real time web application

STEP 1: Weibull Fits

- Fit each pass of POES/MetOp (low altitude) particle fluxes to Weibull functions for 20 years of SEP events (7/01/1998-01/01/2018).

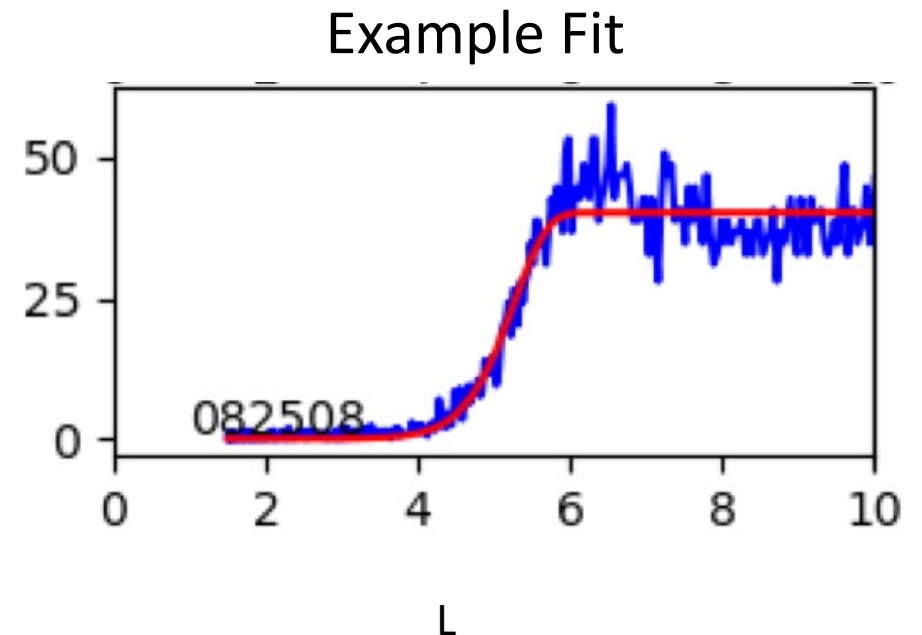
Weibull Function

$$J(L) = J_0 \left(1 - \exp \left[- \left(\frac{L}{L_0} \right)^\gamma \right] \right)$$

J_0 – Flux at large L

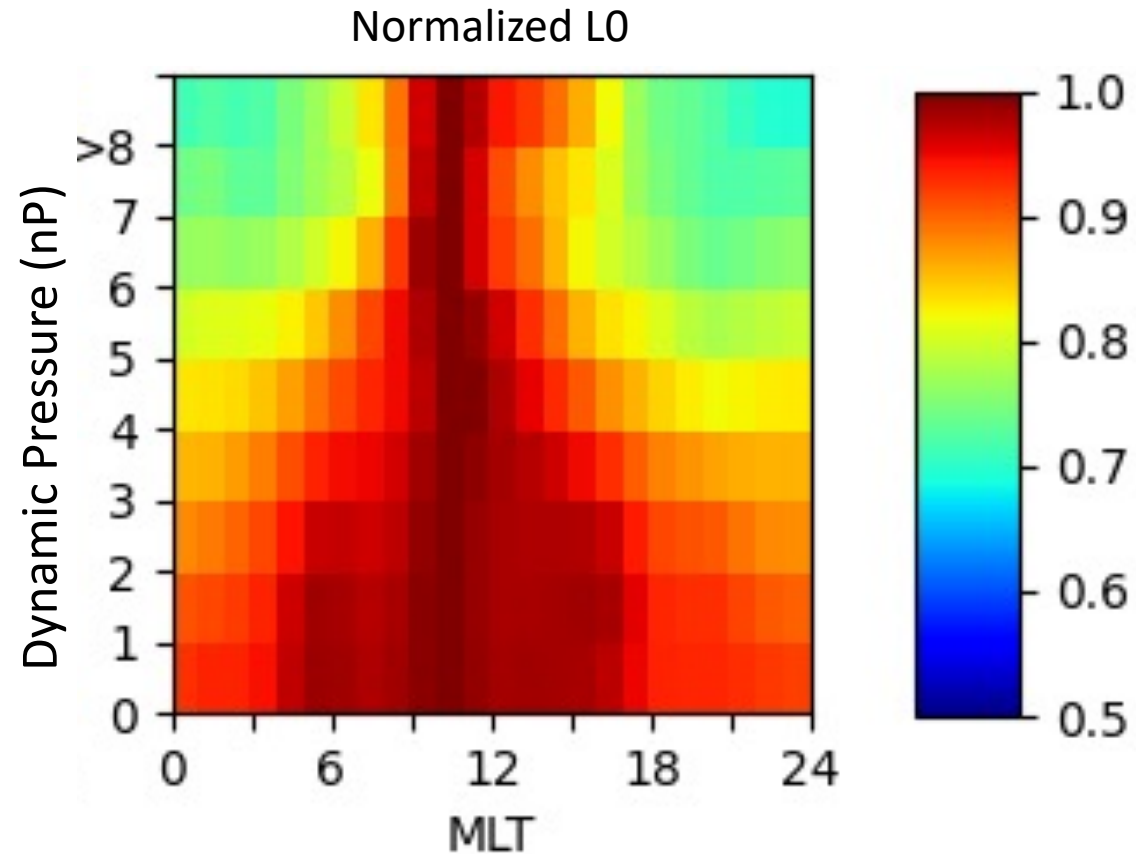
L_0 – location where flux drops to 63%

γ – steepness of the increase



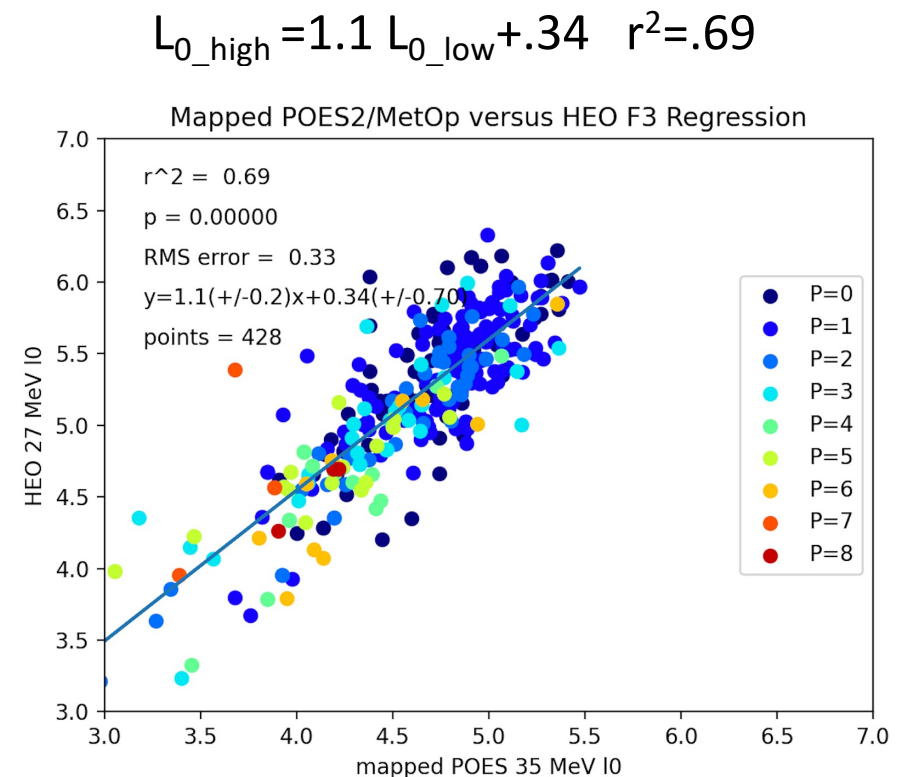
STEP 2: Characterize MLT variation at LEO

- Normalized L0 values as a function of dynamic pressure and MLT



STEP 3: Map from low to high altitude

- Map each L_0 value observed at POES to the MLT of HEO using the MLT/dynamic pressure maps
- Regress the high and low altitude values to define the mapping
- The SPAM correlation is much higher than those obtained when comparing statistical or physics based methods to high altitude data

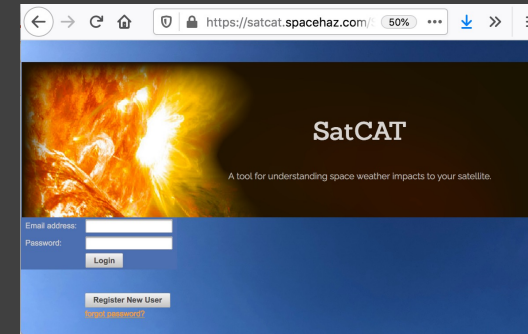


SPAM / SatCAT

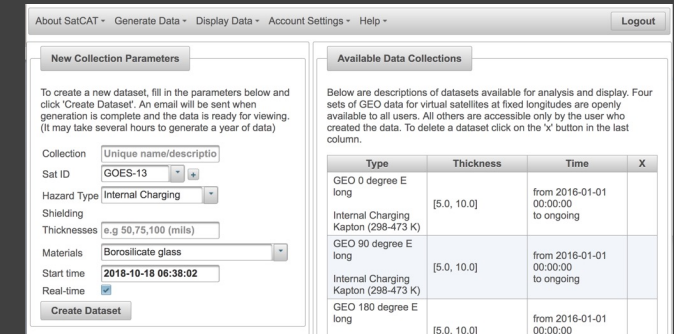
Anomaly Investigation

- SPAM will be integrated into the Satellite Charging Assessment Tool framework that currently gives expected internal charging hazards <https://satcat.spacehaz.com/>
- The application allows users to choose a satellite from the NORAD catalogue and generate a time history of ion fluxes and upset rates for different components that is stored in a database and updated in real time
- Add lists of anomaly times
- Display and analyze

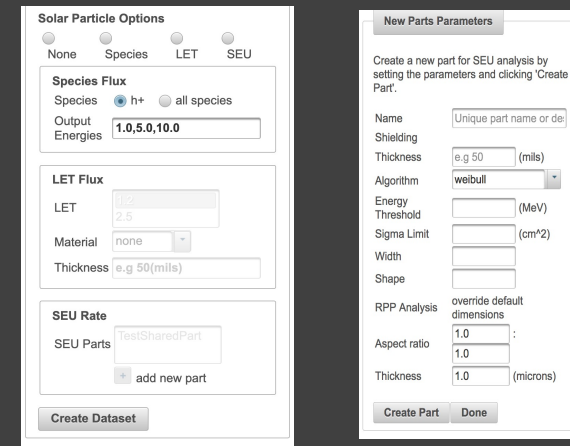
Login



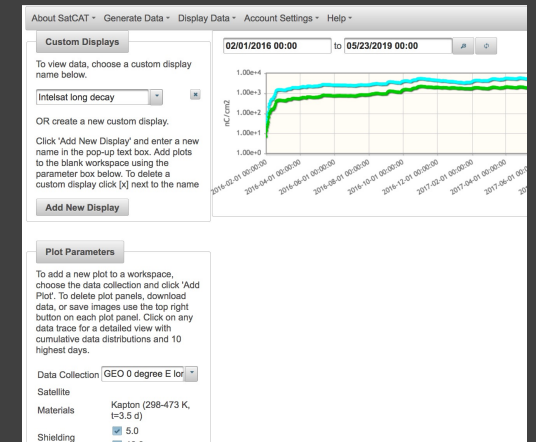
Generate internal charging history



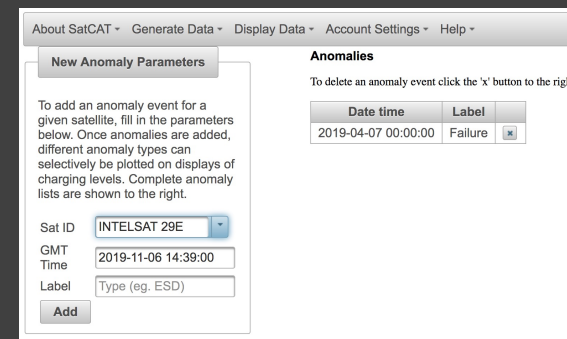
Generate SEU rates



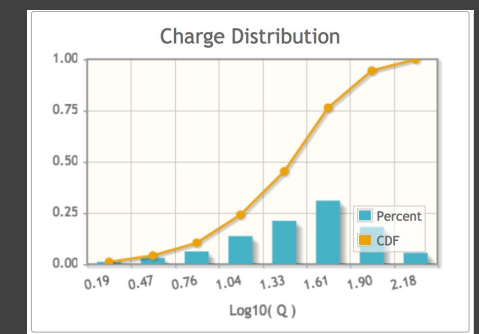
Display data and anomalies



Add anomaly times



Analyze



Summary

The need for satellite anomaly monitoring and forensics tools like SPAM will likely increase as we move into an era that requires coordinating the operation of 10's of thousands of satellites.

SPAM gives a better representation of the solar particle flux near Earth for satellite anomaly monitoring by relying on real time observations.

SPAM captures the flux profile across cutoff boundaries instead of giving single boundary locations.

When completed, SPAM will be easily accessible to satellite operators through an online application for hazard monitoring and anomaly attribution.